Appendix L

California Zebra Mussel Watch Program (CZMWP) staff information

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Appendix M

California Zebra Mussel Action Team (CAZMAT)
Proposed Member Agencies/Organizations and Team Members

Federal Agencies

U.S. Fish and Wildlife Service (USFWS)
U.S. Bureau of Reclamation (USBR)
U.S. Army Corp of Engineers (USACE)
National Marine Fisheries Service (NMFS)
National Oceanic and Atmospheric Administration (NOAA)
U.S. Department of Food and Agriculture (USDA)

State Agencies

CA Department of Fish and Game (CDFG)
CA Department of Water Resources (DWR)
CA Environmental Protection Agency (CAL EPA)
CA State Lands Commission (SLC)
State Water Resources Control Board (SWRCB)
CA Department of Food and Agriculture (CDFA)
CA Department of Pesticide Regulation (CDPR)
CA Bay Delta Authority (CALFED) via

Regional and Local Agencies

Regional Water Quality Control Boards (various)
Water Agencies (various)
City and County agencies (various)

Special Interest Groups

Water treatment plants
Power generation plants
Water companies (Clear Lake)
Marina owners
Recreational boating/fishing organizations
Agricultural interests (e.g. irrigation issues)
Recreational water body related business owners (e.g. lodging, dining, retail)
Watershed groups

Private Citizens

Homeowners
Recreational enthusiasts

Appendix N

California Zebra Mussel Action Teams

Incident Coordinators
(TBD, but suggest CDFG be one agency involved at this level)

Incident Action Team members

1) **Susan Ellis**
Invasive Species Coordinator
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5) **Dr. Rosser W. Garrison**
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Information Dissemination Team members

To Be Determined

Stakeholder Group members

Federal Representatives

1) **David Bergendorf**
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2) **Lia McLaughlin**
Non-native Invasive Species Program
Watershed Coordinator
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Fax (209) 946-6355

State Agency Representatives

1) **Nate Dechoretz**
California Department of Food and Agriculture
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Phone: (916) 654-0768
Fax: (916) 653-2403
Email: ndechore@cdfa.ca.gov

Local Agency Representatives

To Be Determined

Special Interest Groups

1) **100th Meridian Initiative**
(or appropriate individuals representing this organization)
www.100thmeridian.org

2) **Western Regional Panel**
Bettina Proctor
U.S. Fish and Wildlife Service - Region 6
P.O. Box 25486
Denver Federal Center
Denver, CO 80225
(303) 236-7862 x260
(303) 236-8163 FAX
answest@fws.gov

General Public & Media

To Be Determined

Appendix O

Description of CAZMAT Teams and Sub-groups

Main Group/Team	Subgroups/teams	Function	No. Core Members	Role
Incident Coordinators (IC) (incl. Assistant Incident Coordinator)		Lead group, coordinates/runs all large meetings, approves all rapid response activites via Incident Action Team, works directly with Stakeholder group, works directly with all agency management and government officials.	1 - 3 individuals from appropriate agencies	Initiate and implement rapid response actions
Incident Action Team (IAT)		Implements all rapid response activities, conducts all post-introduction, post-treatment acitivites		
	Technical Expertise	Zebra mussel expertise. Advise all groups on zebra mussel biology, monitoring,control/eradication methods. Conduct initial site inspection, confirm zm identification, coordinate/conduct monitoring, control/eradication methods.	3 individuals from academic, agency, private organizations.	Mussel biology, impacts, control
	Operations	Site expertise (including habitat type, structures present, recreation activities, businesses/homes present, resource ownership). Work with Technical Expertise and Logistics sub-teams and appropriate Stakeholder group members to conduct site survey,monitoring, post-introduction treatment.	1-2 individuals (depending on number, size, use of sites)	Site specific info, operations
	Health & Safety	Part of Operations Team - coordinates with various sub-teams during site survey, monitoring and post-introduction treatment activities. Addresses safety items/procures safety equipment.	1 individual w/ appropriate expertise.	Field safety
	Logistics	Determines, requests, receives and coordinates with appropriate Stakeholder sub-groups for resources, staff and supplies needed for site survey, monitoring, and post-introduction treatment activites. Works with Procurement &Facilities, Funding, Operations, Technical Expertise Teams to conduct these activies. Coordinates transportation and communication systems.	1-2 individuals (depending on number, size, use of sites)	Facilitation of monitoring, treatment activities. Organizing resources and staff
	Procurement & Facilities	Part of Logistics Team - orders all supplies needed, addresses lodging and per diem requests, completes rental agreements for equipment, assists with transportation and communication activites. Works with Funding sub-team on budget items.	1 individual w/ appropriate expertise.	Purchasing & securing resources
	Detection& Enforcement	Conducts boat inspections at water bodies or at CA border. Enforces boat cleaning at non-infested waterbodies, prevents launching of infested boats. Coordinates with Technical Expertise, Operations and Logistics Teams during site survey, monitoring and post-treatment activites.	1-2 ind/site Will vary depending on site affected, number of sites	Legal enforcement of detection, prevention activities
	Regulatory	For all rapid response-related activites; Secures required permits and licenses. Determines and coordinates required training. Determines and disseminates information regarding laws, regulations that must be heeded.	1-2 individuals w/ experience in this area. Help of various agency staff in permitting agencies.	Permits and regulations
	Funding	Determines necessary funding needed for all rapid response-related activites. Coordinates with appropriate Stakeholder Group members to acquire funding, establish contracts to receive/disburse funding, establishes necessary MOUs, develops and maintains incident budget for all activites.	1-2 individuals working closely w/ IC and Stake-holder group. Help from appropriate staff in funding agencies.	Securing funding, maintaining budget
Information Dissemination Team				
	Information Dissemination	Collects/disseminates information on all CAZMAT activites within CAZMAT, to media, to government officials. Prepares written reports and articles about CAZMAT activites. Presents information at conferences, meetings, workshops.	1-2 individuals	Experience working with media, government officials and law-makers, writing technical reports
	Public Outreach and Education	Conducts all public outreach/education activities. Prepares and distributes all educational literature. Coordinates with Information Dissemination Team to present information to the public/media during meetings. Presents information about CAZMAT as requested by agency, academic, public, and special interest groups Works with Detection & Enforcement Team to prevent spread of zebra mussels.	1-2 individuals	Experience working with general public, developing outreach materials
Stakeholders Group				
	Federal Agency Reps. State Agency Reps. Local Agency Reps. Special Interest Groups General Public and Media	Participate in CAZMAT as core group/team members. Provide funding, resources, staff for CAZMAT activites. Assist with permitting and licensing activites. Participate in CAZMAT meetings to discuss post-introduction monitoring and treatment options, agency/public concerns. Discuss information dissemination and reporting.	1 individual from appropriate agency/group to serve as core members. No limit on number of individuls to receive CAZMAT information and to attend public meetings.	Provide funding, staff, resources. Provide agency/public comments, opinions ideas.

Appendix P

Zebra Mussel Science Panel Members

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Expertise: zebra mussel biology

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Expertise: zebra mussel biology and experimental control

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Expertise: agricultural pest control

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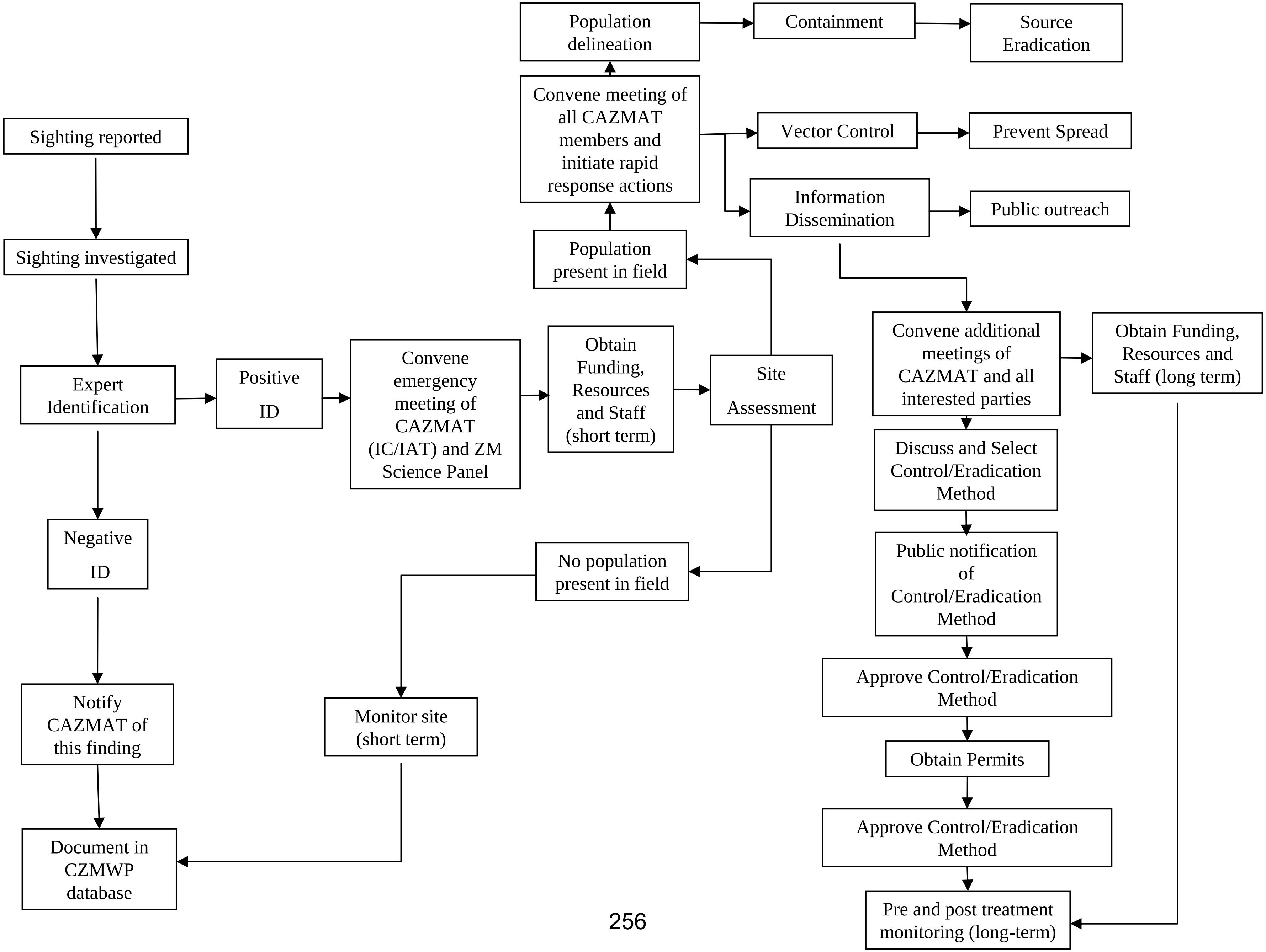
Expertise: CA INS issues and regulations

Need additional members with the following expertise:

- Engineer, knowledge of SWP/CVP, CA water issues, water quality
- California freshwater mussels
- Control/eradication process (e.g. Northern pike experience)

Appendix Q.

Flow Chart of Zebra Mussel Rapid Response Plan


Population delineation
Containment
Source Eradication
Convene meeting of all CAZMAT members and initiate rapid response actions
Vector Control
Prevent Spread
Information Dissemination
Public outreach
Sighting reported
Sighting investigated
Population present in field
Expert Identification
Positive ID
Convene emergency meeting of CAZMAT (IC/IAT) and ZM Science Panel
Obtain Funding, Resources and Staff (short term)
Site Assessment
Convene additional meetings of CAZMAT and all interested parties
Obtain Funding, Resources and Staff (long term)
Discuss and Select Control/Eradication Method
Negative ID
No population present in field
Public notification of Control/Eradication Method
Approve Control/Eradication Method
Notify CAZMAT of this finding
Monitor site (short term)
Obtain Permits
Approve Control/Eradication Method
Document in CZMWP database
Pre and post treatment monitoring (long-term)

Appendix R

Summary of Zebra Mussel Eradication Options

Thermal Shock

Hot water treatment can kill zebra mussels. Temperatures of 37°C and above are lethal to zebra mussels. Depending upon acclimation temperature, zebra mussels will die in about 1 hour. At winter acclimation temperatures (5 to 10°C), temperatures of 33°C and above will kill zebra mussels within 13 hours. For further information, see Table 1 in McMahon et al. (1994).

Desiccation

Instantaneous mortality occurs at 36°C. Temperatures over 32°C are lethal within 5 hours. At temperature below 30°C, time to mortality is dependent upon relative humidity.

Temperature is positively related and humidity is negatively related to adult zebra mussel mortality. As humidity increases and temperature decreases, survivorship increases (Table 1). Aerial exposure of zebra mussels during summer months, when temperatures exceed 25°C, will result in 100% mortality in 2.1 days. During winter months, 100% mortality will take longer, depending upon the relatively humidity.

Desiccation is a viable option for eradicating zebra mussels from areas that can be dewatered for several days. Alternatively, desiccation can also act as a population control method in areas that can not be completely dewatered. For example, reservoir levels can be lowered (at least 30 vertical feet) to expose zebra mussel inhabiting shallow water. The majority of the zebra mussel population inhabits shallow water within 2 to 7 m below the surface, with moderate to low densities up to 50m. Colonization is dependent upon water temperature, oxygen content, and food availability. They tend to colonize above the thermocline.

Table 1. Number of days to 100% mortality of adult zebra mussels aerially exposed to different levels of relative humidity and air temperature. *Research conducted by Dr. RF McMahon and TA Ussery (in Payne, 1992, USACE Technical Note ZMR-2-10).*

	Days to 100 % Mortality at Air Temperature, °C		
Relative Humidity, %	**5**	**15**	**25**
95	26.6	11.7	5.2
50	16.9	7.5	3.3
5	10.8	4.8	2.1

Freezing

Adult zebra mussels die when aerially exposed to freezing temperatures for varying lengths of time. Populations can be controlled by winter-time dewatering and exposing zebra mussels to freezing air temperatures. Zebra mussels die in 2 days at 0°C and at minus 1.5°C, in 5 to 7 hours at minus 3°C, and in under 2 hours at minus 10°C. Duration to mortality is less for single mussels than for clustered mussels.

Research conducted by Dr. RF McMahon and TA Ussery (in Payne, 1992, USACE Technical Note ZMR-2-09).

Oxygen Starvation

Oxygen is removed from the water by cycling it through oxygen-starving pumps. The developer claims the equipment can cycle 200 million gallons of water. This technology was developed by Wilson J. Browning of Amark Corp, Norfolk County, VA. Another method of removing oxygen is to add oxygen scavenging chemicals, such as sodium-meta-bisulfite and hydrogen sulfide gas (USACE-ZMIS). Zebra mussels are able to tolerate oxygen deprivation for up to 2 weeks, provided ambient temperatures are low enough (USACE-ZMIS).

Benthic Mats

Researchers from the Rensselaer Polytechnic Institute in New York are investigating the use of benthic mats that would cover the sediment and zebra mussels, and smother the mussels. Research is planned to occur in Lake George, NY.

Predation

The relatively soft shells of zebra mussels and their exposure (on substrates as opposed to buried in sediment) make them vulnerable to predation. Possible predators of adult mussels are common carp, catfish, bullhead, sucker, sunfish, sturgeon, crayfish, and muskrats. A possible predator of veligers is the American shad. However, there is no evidence of predation control in the Great Lakes, Ohio River, and Poland. There is some evidence of population reduction in the Hudson River. Despite the lack of clear evidence of population control through predation, it is recommended that harvest of predatory species in infested waterbodies be stopped.

Chemical Treatment

The most susceptible life stages to chemical treatment are post-spawned mussels that are in a low energy state, and veligers and pediveligers that have undeveloped shells. There are 3 general categories of chemicals used to treat zebra mussel infestations: metallic salts, oxidizing biocides, and nonoxidizing biocides. Application rates and duration data for these compounds come from laboratory studies, power plants, and water treatment plants.

Metallic salts, electrolytically dissolved metallic ions, are effective on adult mussels because of the incomplete sealing of their shells. The required exposure time for most metallic ions ranges from 5 to about 48 hours.

Oxidizing chemicals have been used by the water treatment industry for disinfection since the late 1800s, and their effect on the environment is understood and documented (Claudi 1995). Zebra mussels can recognize oxidizing chemicals, such as chlorine, as a toxin. Oxidizing chemicals are very irritating. They work by oxidizing the gill lamellae and other parts, eventually causing death. In response to the irritation, zebra mussels expel the offending water and close their valves for several days. Periodically, they reopen their valves to "test" the water. Depending upon water temperature, respiration rate, and stored nutrient reserves, zebra mussels can remain closed and withstand exposure for many days before reopening their valves to resume respiration and feeding. Therefore, required exposure time for oxidizing biocides is usually 1 to 3 weeks.

Zebra mussels do not detect most non-oxidizing chemicals and continue to filter water. The chemical is drawn into the mussel's body and attacks the cell walls. The cells lose the ability to maintain their chemical balance, and the mussel dies. Because the mussels continue to filter, exposing themselves to the chemical, treatment with non-oxidizing chemicals can be accomplished in hours as opposed to weeks.

The most commonly used non-oxidizing compounds are proprietary molluscicides (e.g. Clamtrol, Bulab, Bayluscide). They are applied at high concentrations, and, in most cases, the water must be detoxified after treatment. These compounds are usually deactivated by releasing a slurry of bentonite clay into the water. The cationic or surfactant active ingredients bind onto the clay, becoming inactive. The clay settles out of the water column and becomes part of the bed sediments. The compound is microbially degraded into nontoxic products. These chemicals are less effective at lower water temperatures, so treatment is recommended during warmer months. The chemicals are usually administered with equipment supplied by the vendors.

Non-oxidizing chemicals were used to control the Asian clam in the southeastern US (Green 1995).

Table 2 contains a summary of various chemical treatment options, including treatment concentration, exposure duration, efficacy, affects on non-target species, environmental effects, and registration status. Additional information on most of these chemicals, such as formula, manufacturer, and application method, is available at http://www.wes.army.mil/el/zebra/zmis/idxlist.htm.

Bacterial Toxin

Experimental research is occurring on a toxin produced by *Pseudomonias fluorescens*, a soil bacterium. The toxin destroys the digestive gland of zebra mussels, but reportedly does not harm fish or native mussels. Currently, it is not economically feasible to produce large amounts of the biotoxin.

Appendix S

Eradication and Control Options for Various Zebra Mussel Waterbody Infestation Scenarios

Population Level / Waterbody	Isolated Population	Widespread Population
Pond, Isolated, non-draining	• Evaluate for natural control (e.g. winter freeze, summer desiccation) • Chemically treat area and buffer zone • quarantine, stop all recreational uses in infested area and buffer zone • mandatory cleaning of departing vessels and equipment	• chemically treat entire waterbody • stop water diversions, if any, and chemically treat diversion infrastructure • mandatory cleaning of all departing vessels and equipment • quarantine, stop all recreational uses
Pond, draining	• chemically treat released water or prevent water release • chemically treat area and buffer zone • monitor for spread within pond and downstream • quarantine, stop all recreational uses in infested area and buffer zone • mandatory cleaning of departing vessels and equipment	• minimize or prevent water release • chemically treat released water • chemically treat diversion infrastructure, if any • monitor for spread downstream • chemically treat entire waterbody • mandatory cleaning of all departing vessels and equipment • quarantine, stop all recreational uses
Small Reservoir	• minimize water releases • chemically treat released water • chemically treat area and buffer zone • monitor for spread within reservoir and downstream • quarantine, stop all recreational uses in infested area and buffer zone • mandatory cleaning of departing vessels and equipment	• evaluate need to reduce reservoir volume through water releases • chemically treat released water • chemically treat diversion infrastructure, if any • monitor for spread downstream • chemically treat entire waterbody • mandatory cleaning of all departing vessels and equipment • quarantine, stop all recreational uses
Large Reservoir	• reduce reservoir volume • chemically treat released water • chemically treat infested area and buffer zone • monitor for spread within reservoir and downstream • quarantine, stop all recreational uses in infested area and buffer zone • mandatory cleaning of departing vessels and equipment	• chemically treat released water • monitor for spread downstream • chemically treat diversion infrastructure, if any • evaluate potential for a water level drawdown to reduce the population • evaluate ability to chemically treat entire waterbody • prevent spread to upstream waterbodies and other watersheds • quarantine, stop all recreational uses • mandatory cleaning of all departing vessels and equipment

Population Level / Waterbody	Isolated Population	Widespread Population
River, Small Volume	• minimize or stop inflow and increase upstream water diversions to reduce stream volume and flow rate • install veliger settlement materials at downstream end of population • create pool conditions at downstream end of population to facilitate veliger settlement (e.g., installation of temporary weir) • treat with molluscicide • detoxify downstream of infested area • monitor for spread downstream • prevent spread to upstream waterbodies and other watersheds • quarantine, stop all recreational uses in infested area and buffer zone • installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • mandatory cleaning of all departing vessels and equipment	• minimize or stop inflow and increase upstream water diversions to reduce stream volume and flow rate • treat with molluscicide • detoxify downstream of infested area • monitor for spread downstream • prevent spread to upstream waterbodies and other watersheds • quarantine, stop all recreational uses • installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • mandatory cleaning of all departing vessels and equipment
River, Large Volume	• minimize inflow and increase upstream water diversions to reduce stream volume and flow rate • install veliger settlement materials at downstream end of population • create pool conditions at downstream end of population to facilitate veliger settlement (e.g., installation of temporary weir) • treat with molluscicide • detoxify downstream of infested area • monitor for spread downstream • prevent spread to upstream waterbodies and other watersheds • quarantine, stop all recreational uses in infested area and buffer zone • installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • mandatory cleaning of all departing vessels and equipment	• prevent spread to upstream waterbodies and other watersheds • quarantine, stop all recreational uses • mandatory cleaning of all departing vessels and equipment • installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • closure of unattended boat ramps, esp. in zebra mussel-free areas • mandatory inspection/cleaning of all vessels entering zebra mussel-free waterbodies • evaluate ability to chemically treat

Population Level / Waterbody	Isolated Population	Widespread Population
Delta	• install veliger settlement materials at perimeter of population • divert upstream water to reduce river volume and flow rate (e.g. rock barrier) • create pool conditions at downstream end of population to facilitate veliger settlement (e.g., installation of temporary weir, tidal flow/rock barrier) • treat with molluscicide • detoxify downstream of infested area • monitor for spread • prevent spread to upstream waterbodies and other watersheds • quarantine, stop all recreational uses in infested area and buffer zone • installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • mandatory cleaning of all departing vessels and equipment	• eradication doubtful • implement population level control measures (e.g. salt water intrusion during spawning season and veliger settlement) • prevent spread to upstream waterbodies, other watersheds, pumping plants, and aqueducts/diversion canals • mandatory cleaning of all departing vessels and equipment • closure of unattended boat ramps, esp. in zebra mussel-free areas • installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • mandatory inspection/cleaning of all vessels entering zebra mussel-free waterbodies • establish regulations for ships traveling to/from Ports of Stockton, Sacramento, and Pittsburg • evaluate treatment/spread prevention at all points of diversion (e.g., Contra Costa PP, CVP, SWP, Barker Slough PP)
CVP/SWP Aqueduct	• if only one facility impacted, transfer all diversions to other facility • drain and air dry – 1 week high temps, 2 weeks cool temps, treat standing water with potassium ion or bromine OR isolate infested area and buffer zone with temporary barriers, chemically treat with potassium ion or bromine • treat removed water with potassium ion or bromine • monitor for downstream spread • mandatory cleaning of all vessels and equipment • quarantine, stop all recreational uses of aqueduct	• if only one aqueduct impacted, transfer all diversions to other facility; desiccate and chemically treat infested facility and aqueduct • If both facilities/aqueducts impacted: o treat water before transferring to San Luis Reservoir o chemically treat diverted water and diversion infrastructure (SCVWD and Metropolitan Water diversions) o mandatory cleaning of all vessels and equipment departing San Luis and Bethany reservoirs o quarantine, stop all recreational uses of reservoirs, forebay, and aqueducts o desiccate and chemically treat one facility and aqueduct at a time; continue diversions through other facility • retrofit facility(ies) to minimize impacts

Appendix T

Chemical Treatment Options

Category	Brand Name	Chemical	Formula	Concentration	Application Duration	Deactivator	Effectiveness	Nontarget Impacts	Comments	Approved?	Manufacturer	references	current use
metallic salt		copper ions		5 ppm	24 hours		100% kill					O'Neill. 1996. p.46	
metallic salt		copper sulphate		300 mg/L @ 22.5 C	5 hours		55% kill		can corrode metal pipes			O'Neill. 1996. p.46	
metallic salt		copper sulphate		100 mg/L @ 22.5 C	5 hours		40% kill		can corrode metal pipes			O'Neill. 1996. p.46	
metallic salt		copper sulphate			48 hours		LC50= 2-2.5 mg/L @ 17C; 50% kill at this concentration					Waller et al. 1993	
metallic salt		copper sulphate and sodium hypochlorite		1 to 2 ppm	4 days		black striped mussel					Bax. 1999	Australia, coastal bay
metallic salt		mercury ions		5 ppm	24 hours		57% kill					O'Neill. 1996. p.46	
metallic salt		potassium chloride	KCl		48 hours		LC50 = 150 mg/L; 50% kill at this concentration	2 to 3 times more toxic to zm's than to fish				Waller et al. 1993	
metallic salt		potassium chloride	KCl	>100mg/L			intermediate toxicity;	more toxic to zm's than to rainbow trout and channel catfish					
metallic salt		potassium ion	KH2PO4	160 to 640 ppm	continuous		100% kill	kills native unionid clams at lower concentrations				O'Neill. 1996. p.46	
metallic salt		potassium ion	KCl	50 ppm	48 hours		100% adult kill	kills native unionid clams at lower concentrations					
metallic salt		potassium ion	KOH	>10 ppm			100% veliger kill	kills native unionid clams at lower concentrations				O'Neill. 1996. p.46	
metallic salt		silver ions		5 ppm	24 hours		72% kill					O'Neill. 1996. p.46	

Category	Brand Name	Chemical	Formula	Concentration	Application Duration	Deactivator	Effectiveness	Nontarget Impacts	Comments	Approved?	Manufacturer	references	current use
nonoxidizing		dimethylbenzyl ammonium chloride and dodeclguanidine hydrochloride		1.95 ppm @ 11C	12 hours	bentonite clay	100% kill (after 48 hours post exposure)					Technical Note ZMR-2-14	
nonoxidizing		dimethylbenzyl ammonium chloride and dodeclguanidine hydrochloride		1.95 ppm @ 14C	14 hours	bentonite clay	100% kill (after 48 hours post exposure)					Technical Note ZMR-2-14	
nonoxidizing		dimethylbenzyl ammonium chloride and dodeclguanidine hydrochloride		1.95 ppm @ 20C	6 hours	bentonite clay	100% kill (after24 hours post exposure)					Technical Note ZMR-2-14	
nonoxidizing		dimethylbenzyl ammonium chloride and dodeclguanidine hydrochloride		1.95 ppm @ 20C	14 hours	bentonite clay	100% kill (after 48 hours post exposure)					Technical Note ZMR-2-14	
nonoxidizing; quaternary ammonium compound (polyquat)	Clamtrol CT-1			LC50 values: preveliger=48 microgram/L, veliger=95-179 microgram/L, plantigrade=8.8 mg/L, adult>13mg temperature @ 17C	24 hours	bentonite clay; strongly absorbed to sediment and rapidly degraded microbially to nontoxic products	LC50<1mg/L; fourth highest highest polyquat kill rate; very effective (even at <1mg/L); more effective on veligers than adults; plantigrades least sensitive	toxic to broadspectrum/ nontargets; more toxic to zm's than to rainbow trout and channel catfish; used as a lampricide; greater selectivity than Bayluscide	Virginia Dept Game and Inland Fisheries determined Clamtrol a viable chemical for quarry treatment	previously registered with EPA; have existing enviro data		Waller et al. 1993; Fisher et al. 1994	lampricide
oxidizing agent		bromine					best when pH<8.0	total residual bromine toxic to fish and daphnids @ >80 ppb; toxic to Asian clams @ 1350 ppb; generally toxic to nontargets @ 32 ppb	less enviro harmful than chlorine; component of some proprietary chemicals (e.g. Acti-Brom)			USACE-ZMIS; O'Neill. 1996. p.50	power plant

Category	Brand Name	Chemical	Formula	Concentration	Application Duration	Deactivator	Effectiveness	Nontarget Impacts	Comments	Approved?	Manufacturer	references	current use
oxidizing agent		chloramine		1.2 ppm	24 hours		100% veliger kill					O'Neill. 1996. p.49	
oxidizing agent		chloramine		1.5 ppm	continuous flow through		90% veliger kill					O'Neill. 1996. p.49	
oxidizing agent		chlorine		usually administered to water systems as a gas or as hypochlorite salt (NaOCl)			zm's can detect Cl- in the water, so they stop filtering/close valves; need to treat for many days/weeks	toxic to all aquatic organisms; combines with organic compounds to form THMs and HAAs; highly regulated by EPA because of THMs, esp. if used in drinking water supply; EPA limited is 80 ppb in drinking water				USACE-ZMIS	
oxidizing agent		chlorine		2 ppm	continuous		90% adult kill					O'Neill. 1996. p.49	
oxidizing agent		chlorine		0.25 to 5 ppm	2.9 to 8.8 days at 14.3C 1.6 to 3.7 days at 25.8C		kills settling veligers, not adults					Green 1995	power plant
oxidizing agent		chlorine		0.3 ppm total residual chlorine	14 to 21 days		95% adult kill					O'Neill. 1996. p.49; USACE-ZMIS	
oxidizing agent		chlorine		0.5 ppm total residual chlorine	7 days		75% adult kill					O'Neill. 1996. p.49; USACE-ZMIS	
oxidizing agent		chlorine		applied @ 5.2-8.4 ppm to achieve free chlorine concentration of 0.5-1.0 ppm	21 days, continuous	sodium metabisulphate (NaHSO3); required 4.26-8.15 ppm @ outfall to reduce chlorine level to <0.01 ppm; applied 50% more to ensure compliance; applied dosage = 6.4-12.27 ppm						Command and Matthews. 1994.	
oxidizing agent		chlorine		10 ppm	2 days		100% mortality in 6 days (black striped mussel)						Australia, coastal bay

Category	Brand Name	Chemical	Formula	Concentration	Application Duration	Deactivator	Effectiveness	Nontarget Impacts	Comments	Approved?	Manufacturer	references	current use
oxidizing agent		chlorine dioxide	ClO_2				not as toxic to adults as chlorine	forms chlorite ions, no THMs	must be prepared onsite			USACE-ZMIS	
oxidizing agent		chlorine dioxide	ClO_2	0.5 ppm	24 hours		100% veliger kill; not as toxic to adults as chlorine	forms chlorite ions, no THMs				O'Neill. 1996. p.49	
oxidizing agent		cyanuric acid		2,000 ppm	17 days		50% kill					O'Neill. 1996. p.49	
oxidizing agent		ozone		0.5 mg/L at 15C	10-11 days		100% adult kill	no THMs	outperforms chlorine, reaction time is 3000 times faster; dissipates rapidly in water; instability results in no residual at discharge point; effectiveness dependent upon temperature; unstable, explosive, must generate onsite; difficult to use in flowing systems; expensive equipment			USACE-ZMIS; O'Neill. 1996. p.49	
oxidizing agent		ozone		0.5 mg/L at 15-20C	5 hours		100% veliger and pediveliger kill	no THMs	outperforms chlorine; dissipates rapidly in water; instability results in no residual at discharge point; effectiveness dependent upon temperature; unstable, explosive, must generate onsite; difficult to use in flowing systems; expensive equipment			O'Neill. 1996. p.49	

Category	Brand Name	Chemical	Formula	Concentration	Application Duration	Deactivator	Effectiveness	Nontarget Impacts	Comments	Approved?	Manufacturer	references	current use
oxidizing agent		ozone		1.5 ppm	continuous		prevents settlement	no THMs	outperforms chlorine; dissipates rapidly in water; instability results in no residual at discharge point; effectiveness dependent upon temperature; unstable, explosive, must generate onsite; difficult to use in flowing systems; expensive equipment			O'Neill. 1996. p.49	
oxidizing agent		potassium (Potash)					high zm kill rate	low non-target kill rate	impacts ability to breathe, asphyxiates mussels; Virginia Dept Game and Inland Fisheries determined Potash a viable chemical for quarry treatment				
oxidizing agent		potassium permanganate	$KMnO_4$	2.3 mg/L	16 hours at 21C								
oxidizing agent		potassium permanganate	$KMnO_4$	0.25 mg/L	continuous		prevents settlement	toxic to birds, aquatic invertebrates, and mammals; no THMs or HAAs	less effective than chlorine; turns water pink; used to correct taste and odor of treated water			USACE-ZMIS; Balog et al. 1995.	

Category	Brand Name	Chemical	Formula	Application Concentration	Application Duration	Deactivator	Effectiveness	Nontarget Impacts	Comments	Approved?	Manufacturer	references	current use
oxidizing agent		potassium permanganate	$KMnO_4$	apply at 2-3 ppm; produce aqueous concentration of 0.5 ppm	30 minutes		less than 100% mortality; not acutely toxic to veligers; requires long contact time; concentration varies with temperature	toxic to birds, aquatic invertebrates, and mammals; no THMs or HAAs	less effective than chlorine; turns water pink; used to correct taste and odor of treated water			USACE-ZMIS; Balog et al. 1995.	
oxidizing agent		potassium salts; example, potassium chloride		100 ppm			very toxic to zm's	toxic to nontargets				USACE-ZMIS	
oxidizing agent	ACTI-BROM 1338	soduim bromide and an oxyalkylate (aqueous solution)						toxic to fish and daphnia at less than 80 ppb; toxic to asian clams at about 1350 ppb			Nalco Chemical	USACE-ZMIS	
quaternary ammonium compound (polyquat)	Calgon H-130M	didecyl-dimethyl ammonium chloride		1 ppm	24 hours	5 ppm CA-35 bentonite clay per 1 part Calgon H-130M	100% kill (after 48 hours post exposure)		coagulates mucus layer on gills; inhibits oxygen transfer; adults can't detect toxin so keep filtering; not as effective @ temps below 12C because zm's do not actively feed and reproduce	previously registered with EPA	Calgon Corportation; has application and detoxification equipment; cost of chemical includes Calgon labor costs	Command and Matthews. 1994.	water intake system for industrial plant
quaternary ammonium compound (polyquat)	Clamtrol TM and niclosamide			clamtrol at 20 ppm; niclosamide at 1 ppm	"short-term"	bentonite clay	more effective on veligers than adults		short lived chemical; causes physio stress - interferes with ability to control water and salt balances, causes mussel to swell				

Category	Brand Name	Chemical	Formula	Concentration	Application Duration	Deactivator	Effectiveness	Nontarget Impacts	Comments	Approved?	Manufacturer	references	current use
quaternary ammonium compound (polyquat)	Calgon H-130			LC50 values: preveliger=39 mg/L, veliger=89-175 mg/L, plantigrade=8.8 mg/L, adult=5.6-10mg temperature @ 17C	24 hours	5 ppm bentonite clay; strongly absorbed to sediment and rapidly degraded microbially to nontoxic products	LC50<1mg/L; fifth highest polyquat kill rate; more effective on veligers than adults; equal effectiveness on small (5-8mm) and large (20-25mm) adults	data available on detoxification effects on trout, fathead minnow, and daphnia	coagulates mucus layer on gills; inhibits oxygen transfer; adults can't detect toxin so keep filtering	previously registered with EPA	Calgon Corportation; has application and detoxification equipment	Waller et al. 1993; Fisher et al. 1994; Command and Matthews. 1994	
quaternary ammonium compound (polyquat)	Bulab 6002			4 to 8 ppmm		bentonite clay		toxic to nontargets at lower concentrations	does not readily degrade in water; highly absorptive to sediments and glassware			USACE-ZMIS	
quaternary ammonium compound (polyquat)	Salicylanide I (Sal I)			LC50 values: veliger=1.3-3.2 microgram/L, plantigrade=13.5 microgram/L, adult=55-65 microgram/L temperature @ 17C	24 hours		LC50<1mg/L; second highest polyquat kill rate; more effective on veligers than adults	3 to 4 times more toxic to fish than to zm's	structurally similar to Bayluscide, therefore degradation is probably similar			Waller et al. 1993; Fisher et al. 1994	
quaternary ammonium compound (polyquat)	Bayer 73			LC50 values: veliger=24-28 microgram/L, plantigrade=92 microgram/L, adult=50-56 microgram/L temperature @ 17C	24 hours		more effective on veligers than adults; plantigrades least sensitive					Fisher et al. 1994	

Category	Brand Name	Chemical	Formula	Concentration	Application Duration	Deactivator	Effectiveness	Nontarget Impacts	Comments	Approved?	Manufacturer	references	current use
quaternary ammonium compound (polyquat)	TFM			LC50 values: preveliger=37 mg/L, veliger=2.3-2.5 mg/L, plantigrade=4.2 mg/L, adult=10-11 mg temperature @ 17C	24 hours	significantly degraded by photolysis in aquatic environment	LC50=1 to 150 mg/L; more effective on veligers than adults; TFM less effective on adults than Clamtrol CT-1, Bayer 73, Sal I, Calgon H-130, and Rotenone		significantly degraded by photolysis in aquatic environment; available in benthic release form			Waller et al. 1993; Fisher et al. 1994	larval lamprey
quaternary ammonium compound (polyquat)	Bayluscide					strongly absorbed to sediment and rapidly degraded	LC50<1mg/L; highest polyquat kill rate	more toxic to zm's than to rainbow trout and channel catfish	strongly absorbed to sediment and rapidly degraded; available as 5% granules for release @ sediment-water interface			Waller et al. 1993	
quaternary ammonium compound (polyquat)	Rotenone (Noxfish)			LC50 values: veliger=230-264 microgram/L, plantigrade=275 microgram/L, adult=155-161 microgram/L temperature @ 17C	24 hours		LC50<1mg/L; third highest polyquat kill rate; more effective on adults than veligers and plantigrades	3 to 4 times more toxic to fish than to zm's				Waller et al. 1993; Fisher et al. 1994	
	Evac												power plant
	Baythroid								insoluable in water at concentrations above 100mg/L; insuffiecent mortality at lower doses				
	Buckman Bulab 600203						insufficient mortality						

Category	Brand Name	Chemical	Formula	Concentration	Application Duration	Deactivator	Effectiveness	Nontarget Impacts	Comments	Approved?	Manufacturer	references	current use
	Buckman Bulab 6009						insufficient mortality						
	Calgon DMDACC						insufficient mortality						
	KML V2						insufficient mortality						
	KML V54						insufficient mortality						

Appendix U

In Situ Evaluation Method of Effective Applied Chemical Concentration and Determination of Death

Mortality Monitoring

- Suspend test cages containing attached live mussels into the water to be treated.
- Use at least 10 mussels per cage and multiple cages per waterbody.
- Monitor kill rate as chemical is administered.
- Able to increase chemical concentration based on kill success of mussels in test cages.
- Follow by extensive diver survey looking for live mussels.
- Monitor cages:
    - Conduct mortality count every 24 hours post-treatment application.
    - Transfer to recovery tank and recount in 48 hours.

Determination of “Dead” Mussel

- Valve gaping with no response of exposed mantle tissue to external stimuli.
- Failure of plantigrade mussel with gaping shells to respond to the touch of a probe.
- If shell is closed, then insert probe between the valves of the animal, look for ciliary beating and adductor muscle activity.